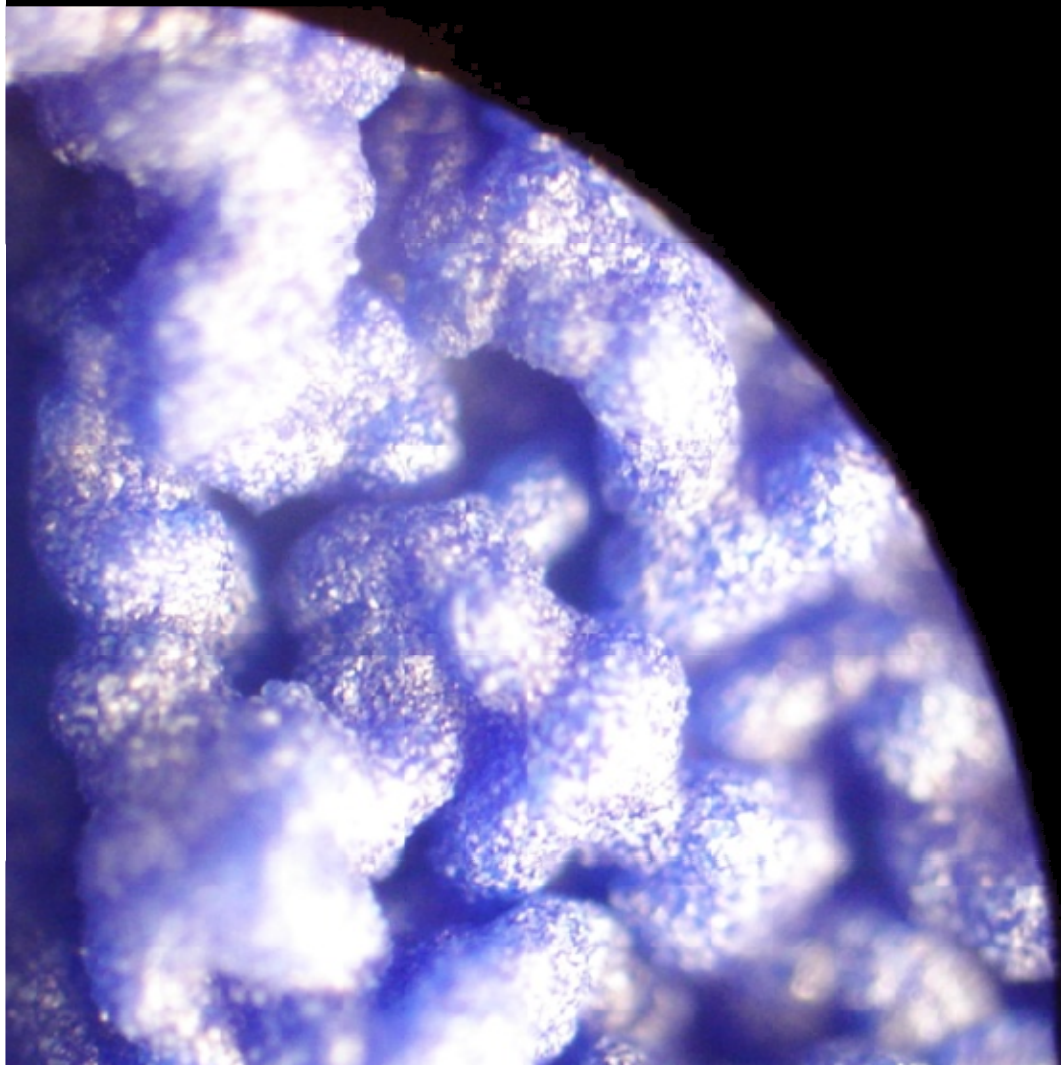


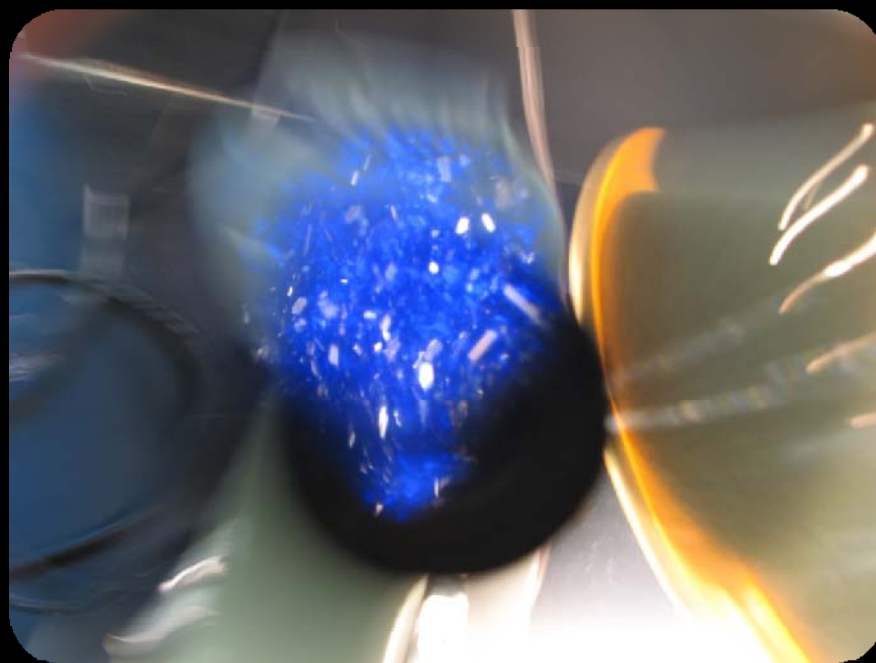
Synthesis of Co-ordination Compounds



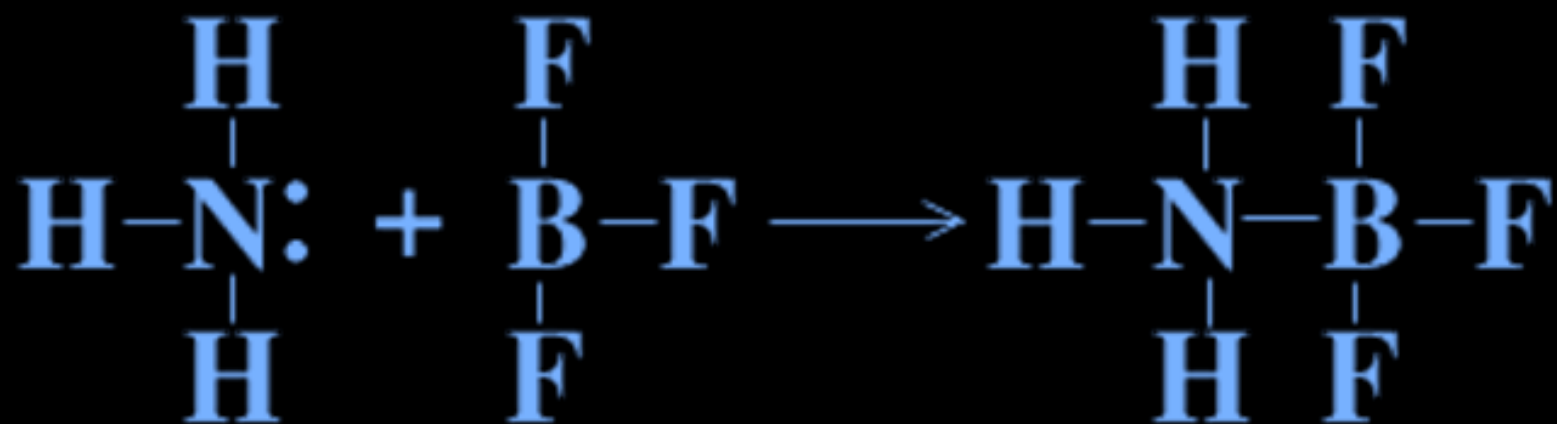
A. Li | H. Lu | A. Muller | G. Ng

Coordinate Compounds

- AKA complex compounds
- Central metal cation with ligands
- Ligands are electron rich
- Coordinate bonds between ion and ligands
- Lewis base and Lewis acid



Example of Coordinate Bonding



Lewis Base Lewis Acid

Valence Bond Theory

- Number of ligands = number of vacant orbitals
- Coordinate bonds indistinguishable
- Hybridization occurs to accommodate all donated electrons

d-orbitals



Empty orbitals filled by e- pair of ligands

Empty orbitals = number of ligands

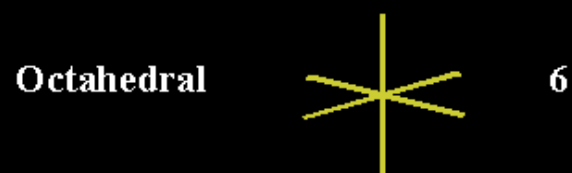
Alfred Werner

- First to explain cobalt chloride and ammonia complexes
 - Number of ligands affect characteristics
 - Coordination number: denotes number of ligands



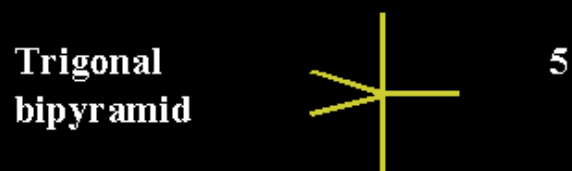
Coordination Number and Geometric Structure

Geometry	No. of ligands	hybridization
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d^2sp^3

- Coordination number determines geometric structure



dsp^3



sp^3

- Two common forms are: square planar, octahedral



dsp^2



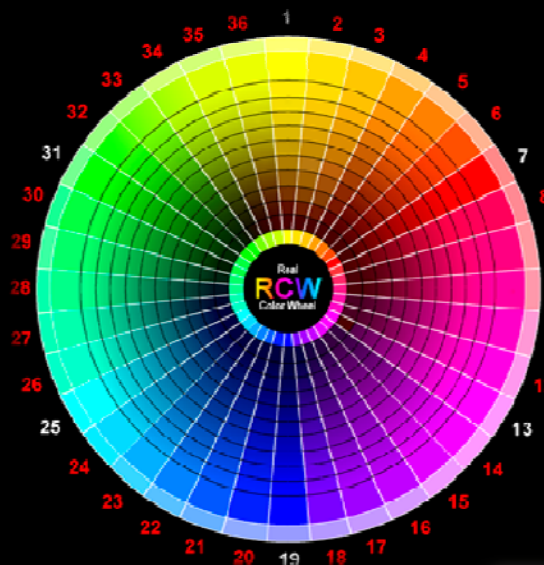
sp

Ligands and Compounds

- Altering the position of ligands relative to one another produces different compounds with the same chemical formula
- Replacing a ligand affects colouring



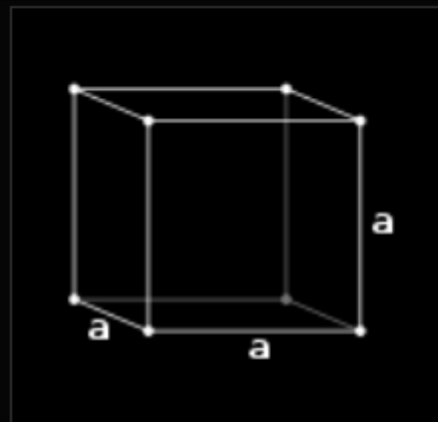
Characteristics of Coordinate Compounds



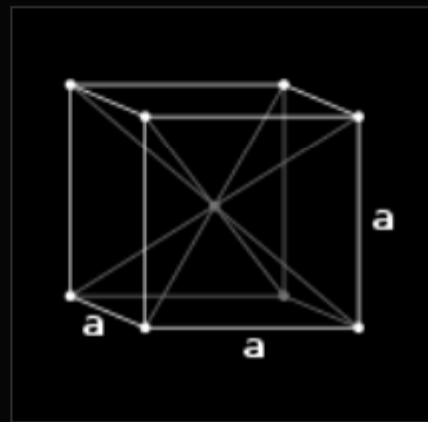
- Colour
- Magnetic susceptibility
- Solubility and volatility
- An ability to undergo oxidation-reduction reactions
- Catalytic activity

Crystal Structures

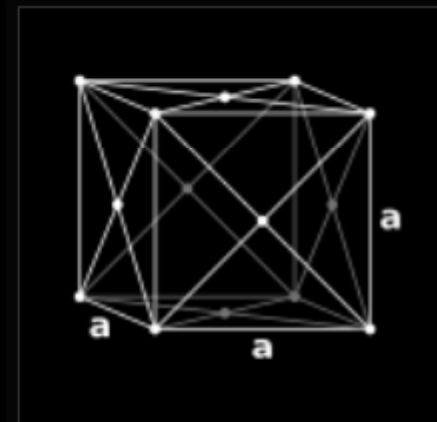
- Unit cells indicate crystal structures
- 3 main varieties of simple cubic:
 - Simple Cubic
 - Face Centered Cubic
 - Body Centered Cubic



Simple cubic



Body-centered cubic



Face-centered cubic

Unit Cell Structure by Group Number

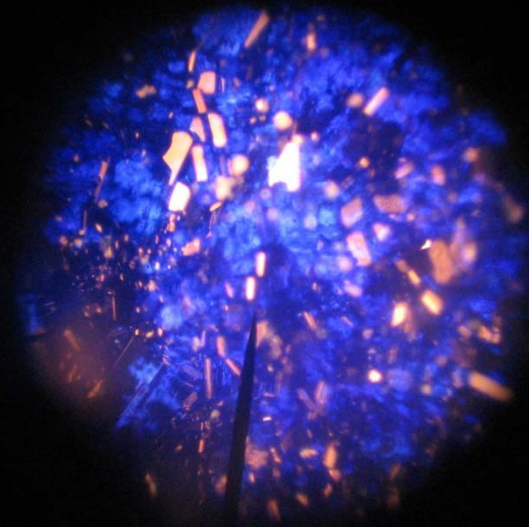
- General trends observed based on group number:

Group #	1	2	3,4	5,6	7,8	9-11
Unit cell	bcc	varied	hcp	bcc	hcp	fcc

- Irregularities include Mn, Fe, and Co

Crystal Structures

- Isometric, orthorhombic crystal systems: crystal systems where the unit cell is FCC
- Other five: triclinic, monoclinic, tetragonal, rhombohedral (trigonal), hexagonal



Crystal Structures

- Cubic or Isometric - not always cube shaped; also includes octahedrons, dodecahedrons
- Orthorhombic - like cubic except not square in cross section with varying heights, lengths, widths → rhombic prisms or dipyrramids



Cubic: halite



Orthorhombic: aragonite

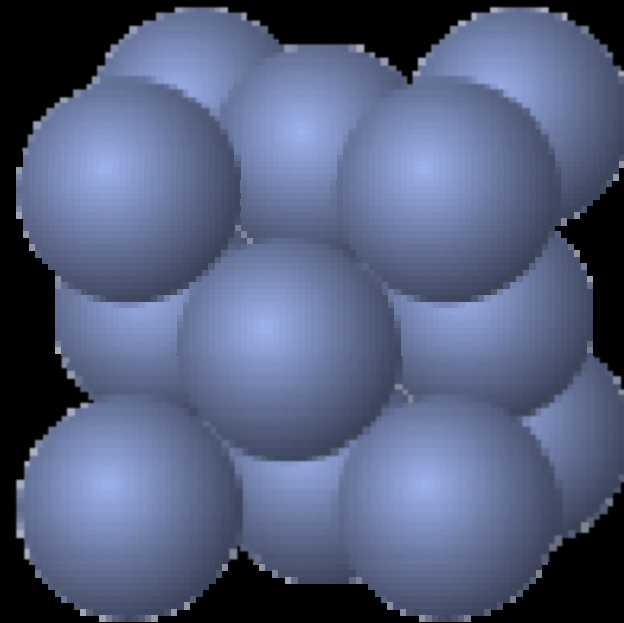
Purpose of Experiment



- Synthesize coordinate compound
- Crystallize
- Study crystal structure

Hypothesis

- Would for a complex compounds \rightarrow ligands
- Crystals contain Cu (group 11)
 - FCC
- Prism-like crystals



Procedure

1. 10g of copper (II) sulfate pentahydrate
2. Add 20 mL of distilled water
3. Stir to dissolve
4. Filter out any impurities



5. Add 20mL of 15M $\text{NH}_{3(aq)}$

6. Add 10 mL of 95% ethanol slowly

7. Ethanol allow liquid to evaporate leaving crystals

8. Remove crystals and view under microscope for further study



Safety Considerations

- Ammonia
 - Caustic
 - Corrosive
 - Fume hood needed
- Ethanol
 - Flammable
- Copper (II) Sulfate
 - Dangerous to the environment



Ethanol burning

Safety Equipment

- Fume Hood
- Goggles
- Plexiglas shield



Observations

Substance	Molecular Formula	Colour	Solubility	Smell
Aqueous Copper(II) Sulphate	$\text{CuSO}_4(\text{aq})$	Clear blue	Soluble (Hydrate)	Metallic
Ammonia Hydroxide	NH_4OH	Clear	Soluble (NH_4^+)	Pungent, stingy



During the Experiment

Substance	Molecular Formula	Colour	Solubility	Smell
Copper(II) Hydroxide	$\text{Cu}(\text{OH})_2$	Blue	Precipitate (OH^-)	Pungent
Ammonium Sulphate	$(\text{NH}_4)_2\text{SO}_4$	Clear	Soluble (NH_4^+)	
Tetraamminecuprate(II) Complex	$[\text{Cu}(\text{NH}_3)_4]^{2+}$	Dark Opaque Blue	Low Solubility	



After the Experiment

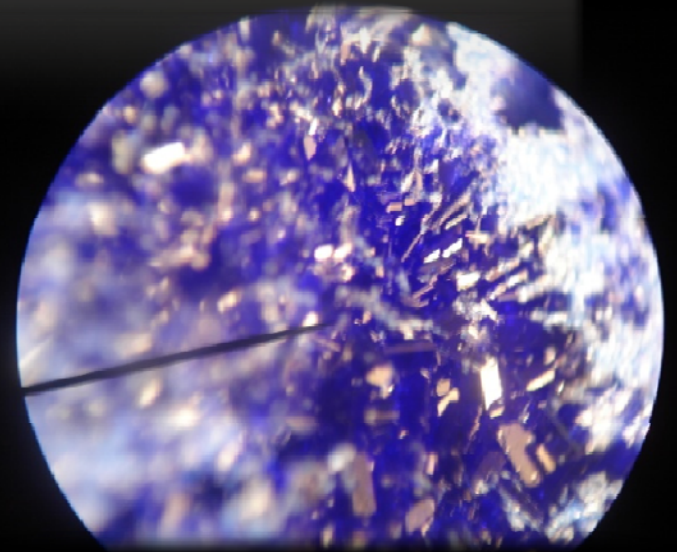
After water has evaporated:

- Viscous substance turned solid
- Crystals formed < 1 mm
- Navy/dark blue mixed with white precipitate



After examining the substance under microscope:

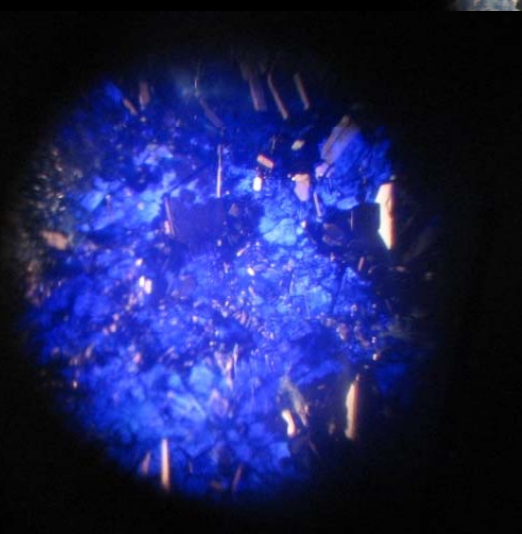
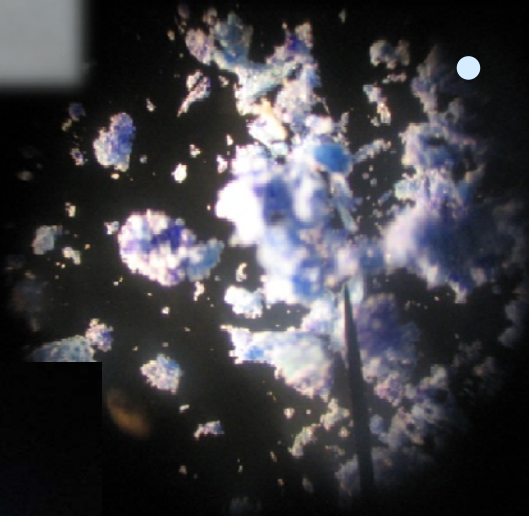
- vivid blue colour
- Overlapping prisms varying heights and similar angles



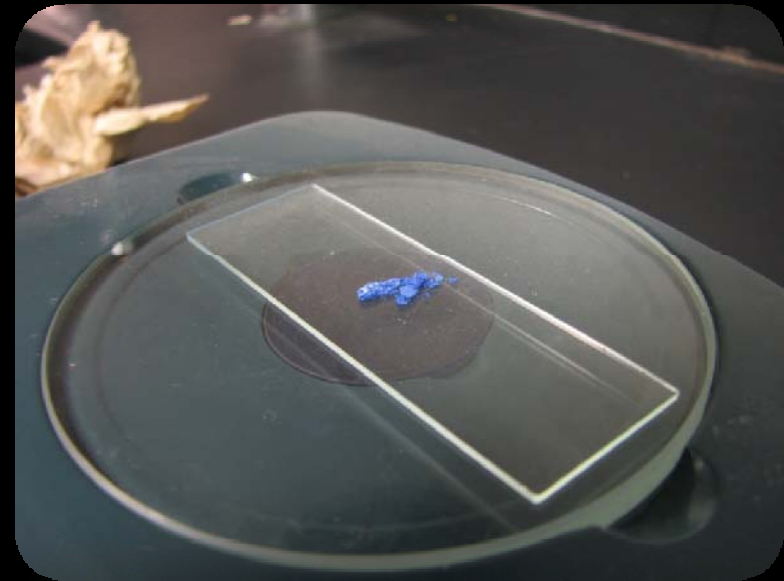
Analysis and Implications



- Colour change due to presence of copper
- Degenerate *d*-orbitals split into high and low energy
 - Photon emission causing colour changes
 - Solution absorbs red and orange (complementary)
 - Resulting colour: blue



- Under magnification
 - Clearest images under medium magnification
 - Light shone at an angle
- Fcc structure can be cubic or orthorhombic from intro
 - Crystals were observed to be orthorhombic
- Experiment #1 and #2 formed better crystal
 - Impurities in solution makes bigger crystals



Calculations

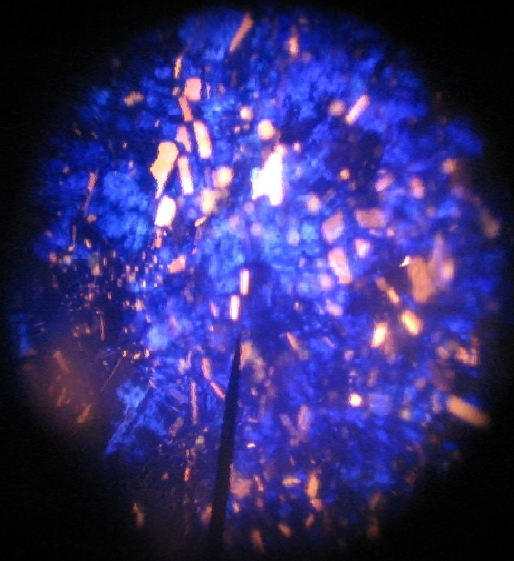
Naming of Compounds

Conclusion



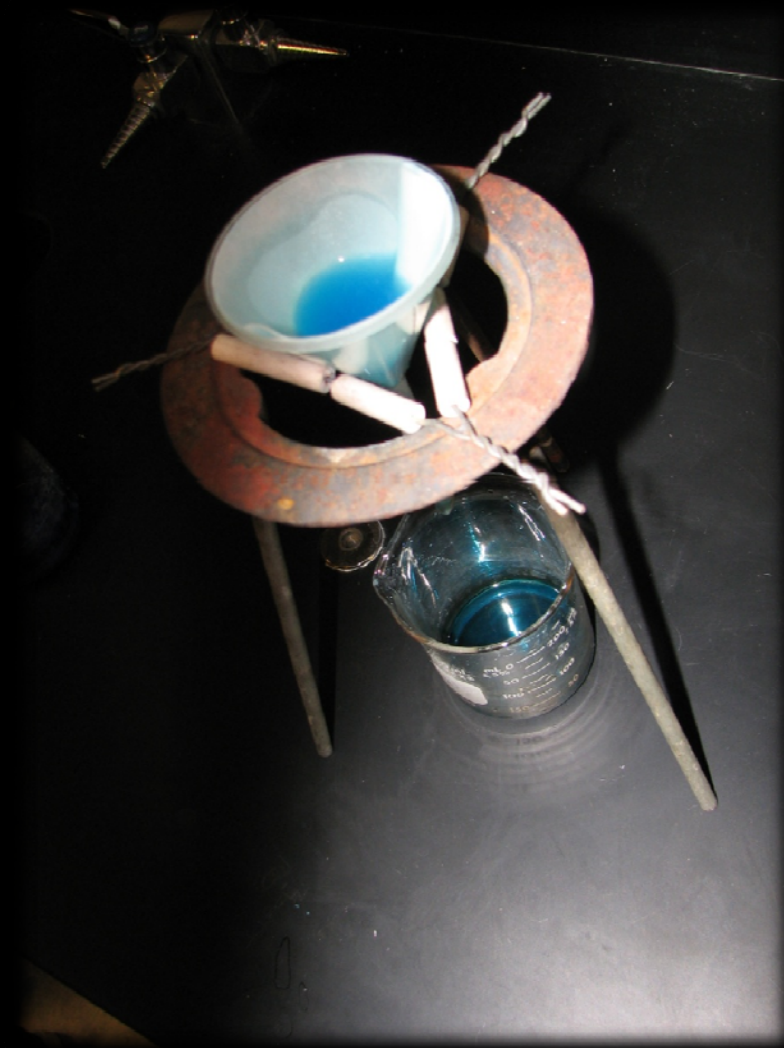
- A coordination compound was successfully
 - synthesized
 - crystallized
 - crystal structure determined
- Tetrammine Cuprate (II) complex created

Conclusion



- Square planar
- Prism structured
- Face Centered Cubic

Experiment Modifications



- Used filter paper and a funnel to filter first
 - Copper (II) Sulphate Pentahydrate mixture was too turbid

Experiment Modifications



- Increased quantity of water (10mL to 20mL)
 - Too concentrated
- Decreased quantity of ethanol (20mL to 10mL)
 - Not as much needed

Sources of Experimental Error



- Systematic (unavoidable)
 - Electric balance reading
 - Quality of substances



- Human (avoidable)
 - Contamination
 - Quantity of substances

Applications

- Found in a variety of areas in everyday life:

Vitamin B12

Hemoglobin

Chlorophyll

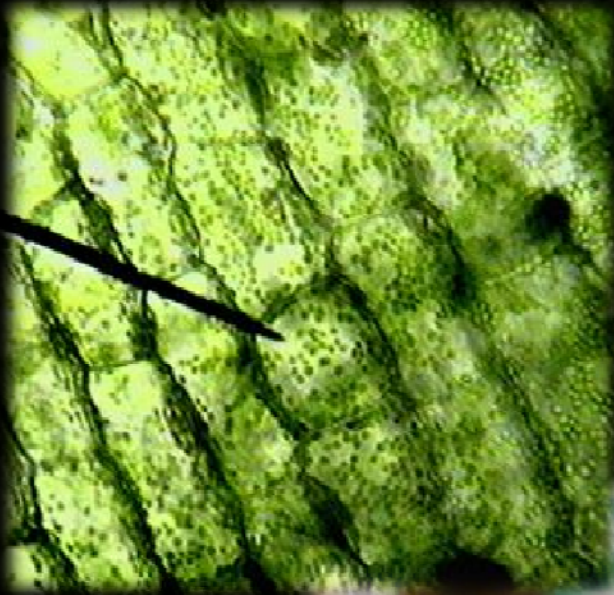
Pigments

Catalysts

- 2 categories:

nature

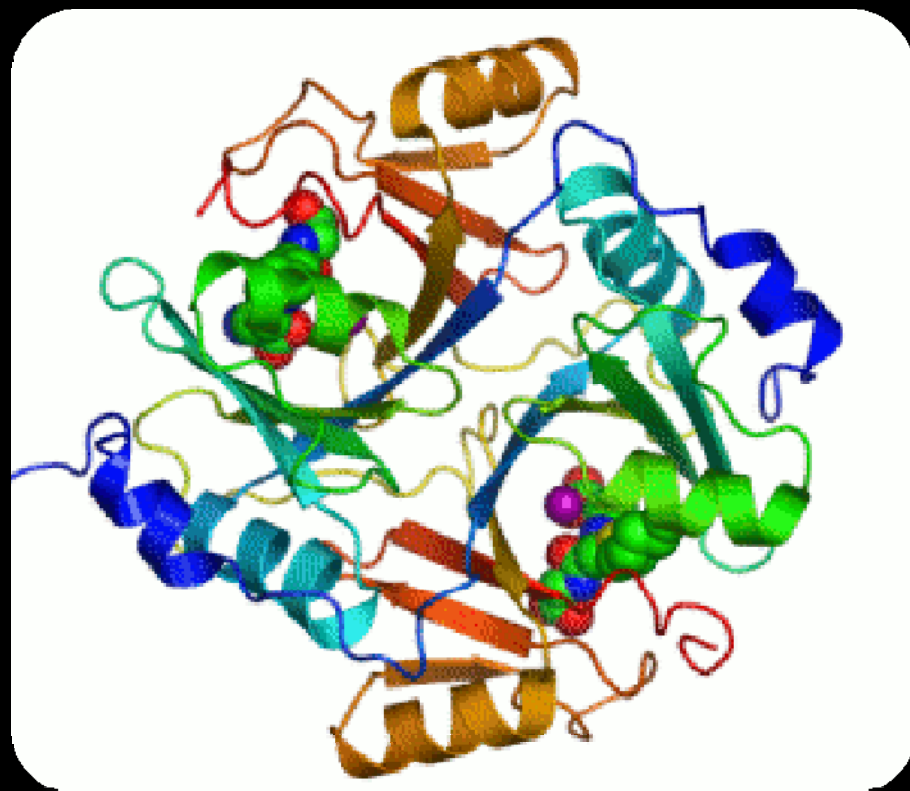
industry



Applications: Nature

- Naturally occurring coordination compounds are vital to living organisms

- Enzymes
(metalloenzymes)



Applications: Industrial Uses



- Catalysts
 - Used in forming polyethylene, polypropylene



Application: Industrial Uses



- Nickel, Cobalt, Copper ore extraction as ammine complex using $\text{NH}_3(\text{aq})$
- Purification of nickel
 - (reacting CO and nickel to form a tetracarbonylnickel complex)
- Often used to soften hard water